VEGETABLES FOR THE HOT, HUMID TROPICS

Part 6. Amaranth and Celosia, *Amaranthus* and *Celosia*

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PREFACE

In the hot, humid Tropics, torrential rains during the monsoon season create special hazards for agriculture. Lands are muddied or flooded, entrance to plantings is restricted, weeds grow vigorously, chemicals applied are washed from the plants, and fertilizer is leached from the soil. High water tables drive oxygen from the soil, diseases thrive above and within the soil, and many plants are uneconomical to cultivate. These conditions make food production difficult, and agricultural skills imperative.

During tropical rainy seasons, the problem of producing highly nourishing food still exists. For the most part, the solution is to select appropriate species and varieties and know how to grow and utilize them in both conventional and unconventional ways.

Tropical diets are often unbalanced not only because of ignorance of sound dietary principles and because of food prejudices, but also because of a lack of good species and varieties. The Tropics are exceedingly varied in this respect, but knowledge is inadequate almost everywhere. Furthermore, even when appropriate varieties are known, it is often difficult to obtain seeds.

The purpose of this series of bulletins is to furnish information about vegetables that can be grown in the hot, humid Tropics. The vegetables covered are either not well known, at least with respect to some uses, or not well distributed, but are productive during tropical rainy seasons. The techniques recommended can be applied on a small scale or with a low level of technology. Seed sources are suggested when necessary.

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VEGETABLES FOR THE HOT, HUMID TROPICS

Part 6. Amaranth and Celosia, *Amaranthus* and *Celosia*

By Franklin W. Martin and Lehel Telek[1]

INTRODUCTION

Among the vegetables of the Tropics, few are as easy to grow as the amaranths (species of *Amaranthus*). Starting from tiny seed, these species can produce delectable spinachlike greens in 5 weeks or less, can continue to produce a crop of edible leaves weekly for up to 6 months, and will then yield thousands of seeds to guarantee their survival. In favorable locations they can reseed themselves automatically and thus continue to produce a useful crop almost without attention. They can also invade plantings of other crops and become noxious weeds, competing with weaker species for light and nourishment. In the Tropics amaranths can produce year-round. For little effort, they afford a nutritious dish with abundant provitamin A, a vitamin particularly necessary in the Tropics for eye health. Amaranths also produce protein efficiently, rivalling or surpassing all other crops in this respect.

Few vegetables are so similar to wild species as the cultivated amaranths. Many of those used as vegetables are weeds that are seldom planted but are almost always present. Seed lots commonly contain both vegetable and weedy forms because weedy forms sometimes hybridize with cultivars in the field. Identification of the

[1]Horticulturist and chemist, Mayagüez Institute of Tropical Agriculture, Science and Education Administration, U.S. Department of Agriculture, P.O. Box 70, Mayagüez, P.R. 00708.

weeds and the cultivars is often difficult, as is preserving good seed stocks.

Few vegetables have traveled so far. Amaranths are now found throughout the Tropics and the Temperate Zone. Vegetable and grain varieties were introduced so quickly after the discovery of the new world that tracing the course of introduction is impossible. And amaranths continue to travel as new interest is expressed in them as vegetable and grain sources. Amaranth enters a region, thrives when cultivated, appears adapted, then frequently dies out from neglect. The process of introduction and trial is continuous.

But few species of vegetables are so despised. The demeaning phrase "not worth an amaranth" exists in several languages. Amaranths are sometimes thought fit only for pigs (hence the common name "pigweed"), and worthy of picking only when poverty forces one to do so. The amaranth is also unwelcome because of its vigorous growth, competitive ability, and enormous seed production, characteristics that are advantageous for amaranth grown as a crop, and that suggest its potential.

Celosia is considered with *Amaranthus* because it is of the same family and has similar growth habits and cultural requirements. It is, in some circumstances, an improvement on *Amaranthus*, being one of the easiest tropical greens to produce.

FIGURE 1.—A dense planting of grain amaranth, *Amaranthus hypochondriacus*.

BOTANY

Taxonomy and Nomenclature

The species of *Amaranthus* and *Celosia* used as vegetables or for grain are given in table 1. This list is not complete, but a complete list would be difficult to develop, because many minor species are used as greens in various parts of the Tropics and because of complex taxonomic problems.

The taxonomic problems of *Amaranthus* occur for several reasons.

FIGURE 2.—A variety of *Amaranthus gangeticus*, used as a leaf vegetable.

First, the species are highly plastic in adaptation (widely adapted and morphologically different according to local circumstances). Second, differences among species often pertain to features that are extremely small. Third, the species probably intergrade, making them even more difficult to recognize. Also, many specific and common names have been used throughout the world, almost interchangeably. The best reference on grain amaranth taxonomy is Sauer (*12*). For amaranths in general, we have used Zeven and Zhukovsky (*15*).

In spite of this confusion, some species are sufficiently recognized to merit universal acceptance. The best of the species for grain is *A. hypochondriacus* L. (fig. 1), and for edible leaves, *A. gangeticus* L. (fig. 2), *A. cruentus* L. (fig. 3), and *A. dubius* Mart. ex Thell (fig. 4).

FIGURE 3.—The amaranth cultivar 'Fotete' (*Amaranthus cruentus*), perhaps the most widespread of the African types.

(Although it is seldom used as a green leaf vegetable, the authors consider *A. hypochondriacus* to have the best tasting leaves of all the species.)

There are fewer species of *Celosia*, and their taxonomy is less controversial, although the species are highly varied. Only one species, *C. argentea* L., is commonly used for food, but the leaves of the others are also edible.

Origin and Distribution

Origins of the cultivated species and secondary centers of variation are given in table 1. *Amaranthus* and *Celosia* species apparently originated in both the Temperate and Tropical Zones in 7 of the 12 "centers of origin" described by Zeven and Zhukovsky (*15*). In addition, these species have become world travelers through their conscious introduction by man or by fortuitous introduction and subsequent establishment.

The current distribution of grain amaranths has been summarized by Sauer (*12*, *13*). The principal species, *A. hypochondriacus*, was derived from the widely distributed wild species, *A. powellii*, probably in Mexico, and was cultivated in pre-Columbian times from Arizona through Mexico. Shortly after the conquest of the New World, *A. hypochondriacus* appeared in various parts of the Old World, where it rapidly became a crop of much more importance. In the 18th century this species was used as a grain in India and Sri

FIGURE 4.—Young and vigorous plant of *Amaranthus dubius*.

TABLE 1.—*Centers of origin and variation of cultivated* Amaranthus *and* Celosia *species and uses*

Center	Species	Notes	Uses
Chinese-Japanese	*A. gangeticus* L.	Center of variation	Leaves.
Indochinese-Indonesian	*A. gangeticus* L.	Center of origin	Leaves.
	A. mangostanus Juslen (*A. tricolor* L. var. *mangostanus*, *A. melancholicus* L.).	Center of origin	Leaves.
	A. paniculatus L.	Possibly the same as *A. cruentus*	Leaves.
Hindustani	*A. angustifolius* Lam.	Center of origin	Leaves.
	C. argentea L.	Center of origin	Leaves.
Mediterranean	*A. lividus* L. (*A. viridis* L., *A. oleraceus* L.)	Center of origin	Leaves.
South American	*A. caudatus* L. (*A. edulis*)	Center of origin	Leaves, grain.
	A. dubius Mart. ex Thell.	Center of origin	Leaves.
	A. hybridus L.	Center of variation	Leaves.
	A. mantegazzianus Passer	Center of origin	Grain, leaves.
	A. spinosus L.	Center of origin	Leaves.
Central American and Mexican.	*A. cruentus* L.	Center of origin	Leaves, grain.
	A. hybridus L.	Center of origin	Leaves.
	A. hypochondriacus L.	Center of origin	Grain, leaves.
North American	*A. hybridus* L.	Center of variation	Leaves.
	A. spinosus L.	Center of variation	Leaves.

Source: Zeven and Zhukovsky (*15*).

Lanka (Ceylon). It became especially prevalent in the foothills of the Himalayas during the 19th century, where it became a staple food used for making bread. It is now important in Nepal, and occurs in China as far north as Manchuria. In Africa it occurs in Uganda, having been taken there by Hindus.

On the other hand, *A. caudatus* (fig. 5), or Inca wheat, is apparently no longer an important grain crop in the Andes (where it is less important than quinoa, *Chenopodium quinoa*). It is now only a minor crop in the highlands of Argentina, Bolivia, and Peru.

A. cruentus from Guatemala is still less used, and is probably the least known species for its grain, although its leaves are still an important crop. As a pot herb, *A. cruentus* is grown in many places, but mostly on a small scale. The choice African variety 'Fotete' is a cultivar of *A. cruentus*.

In spite of a wide distribution of the cultivated species, none can be considered common. Seed supplies are limited to a few varieties from U.S. seed companies. Wherever leaves are eaten some amaranths are known, but these might not be choice varieties, from a horticultural standpoint.

FIGURE 5.—*Amaranthus caudatus* with typical hanging inflorescence.

Weedy amaranths are almost universal in distribution. *A. spinosus*, the spiny amaranth, is widely distributed in the Temperate Zone and Tropics, where it is seldom cultivated, but is often harvested from the wild. *A. lividus* is better known throughout the Temperate Zone.

The distribution of cultivated species in the Tropics is summarized in table 2. The table may not be entirely accurate because names are often used inaccurately in the literature. Nonetheless, the widespread distribution and use of amaranth and celosia is apparent.

Description

Amaranthus and *Celosia* are annual plants that prefer full sun and grow very rapidly from small seed (less than 1 mm in diameter), especially in fertile soils. They develop intermediate to large (0.5 to 2.5 m), erect (but often laterally branched) succulent stems. Profuse lateral branching can be stimulated by cutting back the main stem. Leaves are principally alternate, and simple petioled (almost sessile in *Celosia*). Leaf form varies considerably with species, variety, and stage of maturity of the plant. Leaf texture varies from thin and smooth to thick, leathery, or rugose. Because these plants are extremely flexible in leaf morphology, leaves are not good guides to species identification.

Amaranth and celosia plants are monoecious or dioecious. Flowers are minute and produced in glomerules, combined in dense cymes. Cymes vary in form and are useful for identifying species and varieties. They may be green or pigmented with yellow or red. Male

TABLE 2.—*Distribution of amaranths and celosia in the Tropics, and their importance as vegetables or grains*[1]

Species	Central America	South America	West Africa	East Africa	India and Sri Lanka	Southeast Asia	Pacific Islands
Amaranthus angustifolius	...	L1	...	...	...	...	...
A. caudatus	...	G1, L1	L1	...	G2, L2	G1	...
A. cruentus	L1, G1	L2	L3	...	L2	L3	...
A. dubius	L1	L2	L3	...	L2	...	...
A. gangeticus	...	...	L2	...	L3	L3	L3
A. hybridis	...	L1	L1	...	...	L1	L1
A. hypochondriacus	G2	G1, L1	...	G1	G3	G1	...
A. lividus	...	...	L1	...	L1	L1	L1
A. mangostanus	...	...	...	...	L2	...	...
A. mantegazzianus	...	G3	...	...	...	L2	L2
A. paniculatus	...	...	L1	...	L3	...	...
A. spinosus	...	L1	L1	...	L1	L1	...
Celosia argentea	L1	L1	L3	L1	L1	L2	...
C. cristata	...	...	L1	...	...	L1	...

[1]G, grain. L, leaves. 1, of little importance. 2, of moderate importance. 3, of major importance.

flowers consist of a few tepals and bracts with three to five stamens. Female flowers consist of bracts, tepals, and a spherical ovary that has a single ovule and three stigmas, covered by a cap that abcisses. Flowers may be pollinated by wind, but are often self-pollinated.

Seeds are produced in large numbers. When the pods dehisce, seeds are released and are easily distributed by wind, rain, or animals. After the last seeds are released (some species may produce several seed crops) the plant soon dies.

Some details that can be used to identify individual species are:

Form and branching habits of the inflorescence.
Length of flower bracts (as compared to length of tepals).
Distribution of male and female flowers in the inflorescence.
Tepal conformation (incurved or outcurved).
Seed color.
Flower and foliage pigmentation.
Thickness and form of style branches.

Many of these characteristics must be confirmed with a hand lens or dissecting microscope, but the principal species are easily identified by persons familiar with them. Photographs of cultivated varieties (figs. 1–6) should help identification in many cases.

FIGURE 6.—Young plant of a cultivated variety of *Celosia argentea*.

Genetics and Breeding

The genome or set of chromosomes in *Amaranthus* and *Celosia* is eight or nine. Most species are probably very old polyploids with high numbers of chromosomes that behave as diploids (5). The chromosome numbers of various species are given in table 3.

Walton (*14*) developed a technique for controlled cross pollination of *Amaranthus* wherein a portion of the inflorescence of the male is enclosed with flowers that have been emasculated. But emasculating the flowers requires good eyesight and steady hands.

When plants of two different varieties of *Amaranthus* or *Celosia* are grown side by side, hybridization from wind pollination may occur. Pal and Khoshoo (*10*), working with 10 *Amaranthus* species verified by taxonomists, showed that while species cross freely, the hybrids are characterized by various degrees of sterility, including endosperm malfunction, seedling mortality, foliage deformation, tumorous stems and roots, malformed flowers, and sterile pollen and ovules. The severity of these conditions shows the degree of relationship between species, and species that cross freely with perfectly fertile hybrids can be regarded as varieties of a single species. Pal and Khoshoo found *A. gracilis, A. grazicans, A. lividus*, and *A. tricolor* (several varieties) to be independent species, and that *A. hypochondriacus*=*A. hybridus* and *A. caudatus*=*A. edulis*.

Although *A. dubius* (64 chromosomes) is the only recognized tetraploid, tetraploidy was induced in *A. cruentus* and *A. caudatus* by Misra et al. (9). Fertile tetraploid derivatives were obtained after five generations of self-pollination.

Collections of *Amaranthus* have been developed at the Asian Vegetable Research and Development Center, Taiwan; the International Institute of Tropical Agriculture, Ibadan, Nigeria; the Mayagüez Institute of Tropical Agriculture, Mayagüez, Puerto Rico;

TABLE 3.—*Chromosome numbers of* Amaranthus *and* Celosia *species*

Species	*Chromosome number*	*Species*	*Chromosome number*
Amaranthus caudatus	32	*A. paniculatis*	34
A. cruentus	32	*A. powellii*	34
A. edulis (dubius)	64	*A. spinosus*	34
A. gangeticus	34	*A. tricolor*	34
A. hybridus	32	*A. viridis*	34
A. hypochondriacus	34	*Celosia argentea*	36, 72
A. leucocarpus	32	*C. cristata*	36
A. lividus	34		

Source: Grant (5).

and the Agricultural Research Institute, New Delhi. A comprehensive collection is being developed in the U.S. by the Rodale Experiment Farm, Emmaus, Pennsylvania.

These collections are not necessarily permanent. It is very difficult, moreover, to obtain a wide variety of *Amaranthus* and *Celosia* seeds. They are not in wide demand, and are handled commercially on only a small scale. Celosia has been bred as a garden ornamental, and is known as numerous varieties of cockscomb, but its development as a vegetable has been neglected.

VARIETIES

Selection of varieties for local conditions has been done in India, Puerto Rico, Dahomey, and Nigeria, but very little has been accomplished towards breeding better varieties. And despite the number of amaranth varieties, very few have come to the attention of Western horticulturists. Among those varieties that have, are the following:

'Fotete' (*A. cruentus*) is the favorite variety in South Dahomey (*6*). It is fast growing, upright, succulent, branches little until cut back, reaches a maximum height of 2 meters, and has light-green foliage and ovate or rhomboidal leaves. Its inflorescences are usually terminal, consisting of a panicle of many semiupright branches. 'Fotete' is especially suitable for repeated cuttings, or harvest of young whole plants. A version of this with some pink coloring is called 'Fotete Vert-rouge' in Dahomey.

'Stubby', a very tasty cultivar of *A. cruentus*, is among the varieties at the Mayagüez Institute of Tropical Agriculture (*8*) that merit description. It is vigorous in growth and responds well to harvest by rapidly producing numerous tender side branches. Its foliage is somewhat resistant to insects, and since it flowers quite late, its growth season can be extended to about 4 months.

'Duradera' is a much-branched form of *A. gangeticus* that has dark-green leaves and stem, grows rapidly, recuperates rapidly after harvest, and flowers late, giving it about 3 months of useful life. It is high in vitamin A and higher in protein content than most varieties.

'Crystal' and 'Aupamalip' are similar, attractive varieties of *A. mangostanus* (syn. *A. tricolor* var. *mangostanus*), obtained from Taiwan and Papua New Guinea, respectively. They are rapid-growing, bushy forms that recuperate well after cutting. 'Crystal' has a white petiole and leaf veins similar to those of Swiss chard, and in 'Aupamalip' the petiole and veins are a delicate pink. Maximum productive life is about 3 months.

The variety 'Klaroen' of *A. dubius* is a favorite in Surinam, although it might have come from Indonesia. It has been introduced

successfully to West Africa, from where it is shipped to Europe (especially Holland), where it is a preferred green leaf vegetable.

The variety 'Lal Sag Vert' (perhaps *A. mangostanus*) is a high-yield Indian variety that also has a reddish form, 'Lal Sag Rouge'. This variety produces seed early but has small flowers, and its leaves can be utilized over 5 to 6 months. Many other named varieties are available from India. In the United States the commercially available 'Tampala' is a selected variety of *A. gangeticus* of high quality, but it is better suited to the Temperate Zone than it is the Tropics.

Several varieties of *Celosia argentea* L. have been identified as outstanding. A selection at the International Institute of Tropical Agriculture, Nigeria, designated as 'TLV–8' might be the same as the variety 'Avoumo Rouge' from Dahomey. Another Dahomey variety, 'Avoumo Vert Sauvaze', may be cultivated or wild. The authors have extensively tested the variety 'Sierra Leone', named for the country where collected. All these varieties are very much alike. They establish themselves much more slowly than amaranths, but yield useful foliage over a longer period of time, up to 6 to 8 months. The foliage is dark green, sometimes marked with red, and in the case of variety 'Sierra Leone', is rich in vitamin A.

CULTIVATION

Most of the information on amaranth cultivation is from Grubben (*6*) but the authors have also added material from their own experience. Unless otherwise noted, the following information on cultivation of amaranth also applies to celosia.

Climate and Soil Requirements

Amaranthus and *Celosia* cultivars are warm-season vegetables adapted to the conditions of the hot, humid Tropics, but are also suitable for Temperate Zone summer gardens. As a general rule, these species grow vegetatively during the long days of summer and flower as days begin to shorten. Most varieties will also flower when they have reached a sufficient size, but there is much variation among species (and even among varieties) with respect to this trait.

The amaranths belong to a group of plants called C4 plants, species with efficient photosynthetic abilities that respond best to full sunlight. In common with many other C4 plants, amaranths have rapid, short growth cycles, high net assimilation rates, a low CO_2 compensation point, and a low transpiration coefficient. These characteristics make amaranth a rapidly growing species that yields much foliage, but only for a short time.

Amaranths and celosia are highly adapted and quite efficient at

extracting necessary minerals even from a poor soil. Nevertheless, amaranths have a high potassium requirement, and they benefit more than most plants from careful fertilization. Where amaranths are grown as vegetables, they are frequently cultivated intensively in beds in which the fertility is maintained with large quanities of organic material. Amaranths defy the myth that they are a lazy man's crop by repaying intense care with very high yields.

Soils and Fertilization

Grubben (6) found three kinds of soils useful for amaranth production in Dahomey—sand, heavy clay, and flood-enriched river loam (which needs no fertilization). Grubben recommends a mixture of 10–10–20 N–P–K applied at 400 kilograms per hectare for plants to be uprooted, or at 600 kilograms per hectare for plants to be harvested repeatedly. The use of large quantities (25 tonnes per hectare) of town refuse (noncomposted vegetative material or garbage) is also very useful but does not eliminate the need for mineral fertilizers.

In experiments in Puerto Rico amaranth produced satisfactorily in fertilized soils to which large amounts of compost had been added. Although it is not necessary to use mineral fertilizers for small-scale production, soil fertility should be high.

Seeding and Spacing

Amaranth seeds are small. They must be planted shallowly, covered with fine sand, and watered frequently in order to establish healthy plants. Amaranth seeds are often germinated in a highly fertile seedbed and then transplanted either to an intermediate soil flat, or directly to the field.

In Mexico, grain amaranth plants are established by an efficient process in which mud scraped from lakes or canals is extended in a flat sheet, allowed to partially dry, and is then cut into blocks with a multiple-bladed tool. Small holes are made in the blocks, and a few seeds are placed in each hole, after which the blocks are covered with a fine mulch, and kept moist. The blocks are easily carried to the field for transplanting 4 to 5 weeks after seeding.

A large number of seeds can be established in seed flats, which are convenient for transplanting. A good soil mixture is sand, screened compost or manure, and loam mixed in proportions of 1–1–2 and treated to reduce disease organisms (small amounts of soil can be sterilized in an oven, or the soil in the seed flat can be well wetted with boiling water). Finally, the surface is roughened, seeds are carefully sown over the entire surface, and covered with a fine mulch or straw. Seed flats should be placed in a warm location, but should

not be exposed to drying or direct sunlight or winds. Seeds germinate in a few days, after which the flats should be exposed to full sunlight, with careful control of water. Plants will be ready for transplanting after 3 to 4 weeks.

Because of its weedy nature celosia frequently reseeds itself and volunteers are most likely to be found after the rainy season begins. The plants, scattered among other crops, are often vigorous and productive vegetables in spite of neglect.

Amaranth production is usually managed in carefully prepared, fertile raised beds, or on ridges in rows. Planting in furrows may be desirable when the climate is very dry. The soil where transplanting is to occur should be loose and damp. If plants are to be uprooted, a distance between plants of 10 centimeters is appropriate, but if repeated cuttings are to be made, plants should be transplanted at 20-centimeter intervals. *Celosia* plants require more space, perhaps 30 centimeters between plants.

When possible, transplanting should be done on a cool day or during the cool hours of the late afternoon. Plants should be separated carefully and placed in small holes made with a dibble stick. After placing the plants in the holes, the soil is pushed carefully around the roots, and the plants are watered.

Postplanting Care

Newly established beds of amaranth will grow rapidly, and whether cut repeatedly or harvested in their entirety, they will be ready to harvest perhaps 3 weeks after transplanting. Since amaranths are grown for short periods under intensive conditions, weeds are seldom a problem. The harvest is usually concluded before most weeds are established. But good weed control begins before planting, by maintaining control of weeds in the area, and by avoiding perennial weeds such as grasses that can regrow rapidly. What weeds are found in the beds can be removed by hand before they seed. Beds used for amaranth can be used for other crops later, but should not be allowed to become weedy if they are to be used again. Celosia takes longer to develop and thus requires more efficient weed control.

Control of water is a very important part of postplanting care. As the plants grow, their need for water increases. Plants should never be allowed to wilt, but beds should not be flooded. Light sprinkling controlled by a watering system works well and furrow irrigation can be practical under some circumstances.

PESTS AND DISEASES

Pests that attack amaranths vary from region to region, but diseases are few. *Celosia* is more resistant to pests and diseases than

Amaranthus species, but it is more susceptible to nematodes. For dependability with low care, *Celosia* is preferable.

The most common pest damage suffered by amaranths is caused by the caterpillars of various types that are found throughout the Tropics (especially *Hymenia recurvalis* F. and *Prodenia litura* F.), but some insects bite or sting the leaves, producing small spots. In Dahomey, caterpillars are treated by spreading wood ashes around the plants, but this is not effective. Insects have proved very difficult to control in Puerto Rico unless insecticides are used or the plants are grown in such special environments as greenhouses or isolated small plantings. Insects can be a limiting factor on the use of amaranth leaves. *Celosia* plants, on the other hand, are seldom devestated by insect attacks.

Nematodes, especially root-knot nematodes (*Meliodogyne* spp.), frequently attack amaranths, but cause little damage. And although the authors have seen tumorous roots on *Celosia* attacked by nematodes in Puerto Rico, the plants continue to grow prolifically.

Grubben (*6*) describes several diseases of amaranths in Dahomey. Young seedlings may be attacked by damping-off organisms (chiefly *Pythium* spp. and *Rhizoctonia* spp.) which may be controlled by avoiding over-watering and poor drainage. Disinfection of the soil is also useful, and can be accomplished by burning dry refuse on the surface of the soil before planting. Fungicides used for other seeds might also be effective.

The principal disease of the mature amaranth plant is a fungus disease, a wet rot of leaves and young stems associated with hot, humid weather and caused by *Choanephora cucurbitarium* Thaxter. It is spread through infection of insect-caused lesions and is controlled by use of the least sensitive varieties (such as 'Klaroen') and by use of good cultural methods to promote rapid growth.

HARVEST AND YIELDS

Amaranth leaves can be harvested any time after planting. If the seeds are sown by broadcasting, and seedlings are thinned by hand, the discarded seedlings make an excellent vegetable.

In Dahomey, young amaranth seedlings grown for commercial purposes are often uprooted when they are 30 to 40 centimeters high, and around 6 to 7 weeks old, 3 to 4 weeks after transplanting. But by delaying harvest only 2 more weeks, yields can easily be doubled.

The more common practice is to harvest amaranth and celosia by repeated cuttings. The first cutting can be made as soon as 3 weeks after transplanting, as long as no more than 50 percent of the green leaf material is removed. Subsequent cuttings are made at intervals of 1 to 2 weeks, or as necessary, each slightly higher than the previous

cut. As many cuts are made as possible until flowering begins and suitable vegetative material is no longer available. Severe cutting tends to delay flowering but can also reduce yields. Cutting amaranth and celosia for maximum yields is something of an art; exact rules cannot be given. Time of cutting depends on species, variety, time of year, and cultural treatment.

Amaranths grown for seed are not usually harvested for greens, although light harvesting of leaves can be done without significantly changing seed yields. Seeds for regenerating the leafy varieties are produced by leaving especially vigorous plants unharvested. Such seed plants are watched carefully after flowering. When mature seeds can be rubbed from the inflorescence, the plants are cut and removed for drying and threshing. When thoroughly dry, the inflorescences are rubbed, sometimes on a screen, to loosen and remove the small seeds. These may be separated from the chaff with fine screens and, if necessary, by winnowing.

The amaranths used for edible grains are less likely to shatter than plants of leafy varieties grown for seed. The inflorescence of *A. hypochondriacus* can dry in the field, if carefully watched. If cut before fully dry the stalks may be laid to dry in the fields. The dried flower heads are hung over cloths and beaten to release the seeds. Finally, the seeds are screened, and the cleaned seeds are stored until used. Their storage qualities are excellent (*3*).

Yields of leaves are very high compared to other vegetables. Dry-matter production has been measured as 2.7 tonnes per hectare of amaranth or 2.3 tonnes per hectare of celosia in only 6 weeks. Grubben (*6*) estimates that with improved techniques, dry-matter production of amaranth can be increased to 3.5 tonnes per hectare in 4 weeks. With proper soil care, amaranth can be produced on an almost continuous basis, thus providing yields of vegetables, dry matter, protein, and vitamins A and C that would probably surpass records for almost all other crops.

UTILIZATION AND NUTRITIONAL VALUE

Uses

Although amaranth and celosia leaves are normally used as a pot herb or spinach dish, the techniques vary. Normally, the leaves (including the terminal and softest portions of the shoots) are stripped from the stems and washed and boiled in several changes of water for 10 to 15 minutes. They are rinsed again, and the cooling water is discarded (to remove part of the oxalic acid). The leaves may then be served as a side dish or combined with other foods to make stews. In West Africa they are pureed and combined with other ingredients in

a sauce that is used with farinaceous vegetables. Different amaranth and celosia varieties have different flavors. Pink- and red-pigmented forms are often less desired because they "dirty" the cooking water. Amaranths can be adapted to recipes for other leafy vegetables. Twelve recipes for the use of leaves, and three for the use of seeds are given in the "Amaranth Roundup"(*1*).

In Mexico, grain amaranth is used chiefly for making alegria candies, which are made by popping the grains over a hot plate, and then combining them with a thick, hot sirup to form balls. The balls are forced into a mold, rolled flat, and cut into strips (*3*). Pinole, a sweetened flour, is made by grinding popped seeds into a fine flour and adding sugar. For festive occasions, a type of tamale is made with flour ground from unpopped seed, which is then mixed with sirup and other ingredients and patted into a ball. Amaranth seeds are also ground and cooked in boiling water to develop a nutritious and soothing drink.

In other parts of the world, amaranth seeds are ground to a fine powder and used as flour in unleavened bread, or mixed with wheat flour for leavened breads. Recipes for such are also given in the "Amaranth Roundup" (*1*).

Composition and Nutritional Value

Although leaves in general are good sources of vitamins A and C, calcium, and iron, they vary widely in nutritive value. Even leaves of a single species vary among varieties and according to the condition of the plant, age of leaf, and so on. The composition of leaves of *Amaranthus* and *Celosia* species is summarized in table 4.

Expressing nutritional data terms of in dry-matter content makes it possible to compare all foods to each other, even though foods are seldom eaten dry. This technique shows that amaranth leaves are fair to very good sources of protein. Their carbohydrate content is also fairly high, and this includes a considerable amount of indigestible fiber (also a necessary element in the diet). The lipid content is almost negligible.

Among the vitamins, vitamin A (as carotene) is found in high concentrations. Vitamin C content is also very good, but B vitamins are not found in large quantities in leaves. Of the minerals, calcium and iron are plentiful. The iron is readily used by the body but the calcium is not, because of the rather high (5 to 14 g/100 g dry weight) oxalic acid content of amaranth leaves.

The seeds (on a dry weight basis) are similar to the leaves in protein and fat, but have much less of vitamins A and C, and much more of the B vitamins and carbohydrates.

Celosia's nutritional content is similar to amaranth, but its protein content is less.

FUTURE PROSPECTS AND RECOMMENDATIONS

Constraints to Wider Use

As a green leaf vegetable amaranths and celosia have a serious drawback. Their high oxalic acid content is a problem shared with a number of leafy vegetables in other families, including spinach, *Spinacea oleracea* L. Because oxalic acid interferes with calcium uptake in the human body, the amount of amaranth or celosia in the

TABLE 4.—*Composition of leaves of some* Amaranthus *and* Celosia *species and of* A. hypochondriacus *seeds*
[Per 100 g dry weight]

Constituent[1]		*A. caudatus*	*A. gangeticus*	*A. hybridus*	*A. hypochondriacus*[2]
Dry matter	%	29.9	14.3	. . .	88.9
Proteins	g	17.4	28.0	33.5	16.3
Lipids	g	1.0	3.5	4.0	5.8
Carbohydrates	g	19.4	43	34	71.8
Fiber	g	5.35	7	. . .	. . .
Vitamin A	IU	25,400	23,000	. . .	. . .
Vitamin C	mg	210	693	. . .	1.5
Vitamin B_1	mg	. . .	0.02	. . .	0.77
Vitamin B_2	mg	. . .	2.1	. . .	0.78
Vitamin B_3[3]	mg	. . .	8.4	. . .	1.5
Calcium	mg	1,538	2,776	3,280	154
Iron	mg	16.0	17.8	7.0	13.8
		A. paniculatus	*A. spinosus*	*A. viridis*	*C. argentea*
Dry matter	%	21.4	17	6.0	12
Proteins	g	27.6	31	38.3	16.7
Lipids	g	4.7	1.8	1.7	5.8
Carbohydrates	g	40	34	21.7	48.3
Fiber	g	9.8	9.4	13.3	13
Vitamin A	IU	40,000	54,110	48,000	. . .
Vitamin C	mg	379	250	147	. . .
Vitamin B_1	mg	0.05	. . .	. . .	. . .
Vitamin B_2	mg	1.12	. . .	. . .	. . .
Vitamin B_3[3]	mg	5.1	. . .	. . .	. . .
Calcium	mg	2,477	1,042	2,250	2,692
Iron	mg	8.6	10.3	7.6	. . .

[1]Per 100g dry weight.
[2]Seeds.
[3]Nicotinamide.

Sources: Elias (*4*), Grubben (*6*), and Rosedale and Milsum (*11*).

diet should be limited. But that limit is probably far greater than the amount of amaranth most people would want to consume anyway. A good diet should contain many kinds of green-leafed vegetables to avoid the problem of toxic substances present in some species or groups of leaf vegetables.

A second problem with amaranth is its susceptibility to insect pests, particularly leaf-eating caterpillars. Where these occur (which is apparently throughout the Tropics), they can devastate a planting very rapidly. Leaves with holes may be nutritious, but they are not attractive, and are seldom salable. Celosia does not have this problem.

Grain amaranths, on the other hand, are not used more widely because they compete with other grains, some of which are easier to produce and more productive. Furthermore, grain amaranths are best adapted to highlands and are not suited to the humid Tropics except during the dry season. The plants are easily lodged after heavy rains, and the heads of seed do not dry out properly.

The chief constraint to wider use of celosia varieties is their slow initial growth. But for small farms, the longer growing season and higher total production are an advantage.

Plant-Breeding Potential

The possibilities of developing improved varieties of amaranth have not been tested thoroughly. So far, collections have been superficial and no attempt has been made to determine the range of variation within each species. Breeding of the grain amaranths in India has been confined principally to materials already there. Nevertheless, there is reason to believe that amaranths and the related celosia can be successfully bred. Ornamental varieties have been developed that demonstrate wide variations in color and morphology. Since some of these were selected or developed by unskilled persons, we may look forward to even greater advances from the application of advanced techniques. Most species are diploids, and rapid progress can also be expected from traditional techniques. Since the species are wind pollinated, simple techniques can be used to effect numerous crosses.

Breeding goals for the green-leaved vegetables should include development of lines with low oxalic acid content and with insect and disease resistances. Characteristics such as flavor, quality, and yield are generally acknowledged to be suitable in existing varieties. In the case of the grain amaranths, better plant types would have more biomass as seeds in place of stem. Active investigation of the potential of grain amaranths has been initiated in California (7), and research goals are being formulated.

Probable Future Roles

There is currently a great deal of interest in amaranth. Increased use of the grain-producing forms should occur as the advantages of this crop become widely known. Although amaranth probably will not replace any current grain crop, it will supplement such crops in difficult areas.

But neither the vegetable varieties of amaranth, nor celosia are likely to be used on a wider scale unless complex circumstances that include value judgments change. They are not typical Western vegetables and are not readily accepted by the millions of poor who need them most. Better education is needed to teach people to appreciate these and other fine vegetables already available (but heretofore neglected) in the Tropics.

Species of *Amaranthus* and *Celosia* have been considered as sources of leaf protein concentrate (2) because of their high protein content and rapid growth rates. Although the conventional heat fractionation process does not precipitate proteins, and white protein cannot be separated by any current method, the possibility of using leaves as a source of protein concentrate has not been eliminated.

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